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*Review Article*

# Water, Sanitation, and Hygiene (WASH) Gaps as Drivers of Antimicrobial Resistance in Sub-Saharan Africa: A One Health Perspective

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**Abstract:**
Antimicrobial resistance (AMR) is a growing global threat, and sub-Saharan Africa (SSA) bears a disproportionate share of this burden. This narrative review examines how deficiencies in water, sanitation, and hygiene (WASH) contribute to AMR in SSA. It draws on peer-reviewed literature, institutional reports, and regional policy documents published between 2015 and 2025. Sources were identified through databases such as PubMed, Google Scholar, and WHO/UN databases using combinations of keywords including 'AMR', 'WASH', 'Sub-Saharan Africa', and 'One Health'. We survey recent literature on the regional AMR problem, the role of inadequate WASH in propagating resistant infections among humans, animals, and the environment, and the relevance of a One Health approach. Key themes include the high AMR mortality in Africa, the persistence of antibiotic residues and pathogens in poorly managed water and sanitation systems, and how poverty-related WASH gaps drive frequent infections that require antibiotics. Evidence suggests that unsafe water and sanitation facilitate the environmental circulation of resistant bacteria and genes. The One Health framework is highlighted as essential for addressing these links, since AMR crosses human, animal, and ecological domains. We conclude that improving WASH infrastructure and practices, alongside integrated AMR strategies, is critical to curb resistance in the region. Focusing on WASH under a One Health perspective can reveal overlooked pathways of AMR spread and inform targeted interventions in SSA.

**Keywords:** Antimicrobial resistance; WASH; One Health; Sub-Saharan Africa; Infection Prevention; Environmental Health; AMR Policy

## Introduction

Antimicrobial resistance (AMR) is a rapidly rising global health crisis. WHO emphasizes that AMR already causes disproportionately high mortality in low- and middle-income countries due to heavy infectious disease burdens and limited resources (1). A recent report indicates that the African region has the highest global mortality rate from antimicrobial resistance, with 27.3 deaths per 100,000 population (2). These findings underscore that sub-Saharan Africa (SSA) is particularly hard-hit by drug-resistant infections, which compound existing health challenges. This is often attributed to infrastructural deficits in water, sanitation, and hygiene, and is further embedded in broader structural vulnerabilities (3). Weak governance, under-resourced health systems, and inadequate regulatory enforcement hinder the translation of policies into effective action (4). Limited diagnostic and laboratory capacity prevents early detection of resistant infections, while cultural practices such as open defecation, reliance on informal food markets, and indiscriminate use of antimicrobials in livestock production amplify exposure pathways (5).

Water, sanitation, and hygiene (WASH) interventions are foundational but often neglected measures for infection prevention and AMR mitigation (5). The World Health Organization explicitly identifies improvements in water, sanitation, and hygiene, as well as wastewater management, as "critical elements of preventing infections and reducing the spread of AMR." (5). Conversely, inadequate WASH enables resistant bacteria and antibiotic residues to persist and spread through contaminated environments (6). Accordingly, one analysis notes that poor sanitation and a lack of safe water in Africa make infection avoidance extremely difficult, thereby compounding the transmission of AMR (7). In practice, the lack of clean water and sanitation facilities means that many infections go unchecked or require antibiotic treatment, creating selective pressure for resistance (7, 8).

SSA's vulnerability to AMR arises not only from WASH gaps but also from interrelated socio-economic factors. Many communities lack reliable access to safe water, improved sanitation, and hygiene services, driving a high incidence of preventable infections (e.g., diarrheal diseases, typhoid, cholera) that often require antibiotics (9, 10). Crowded living conditions and close contact with livestock and wildlife further accelerate the spread of resistant pathogens (11). For instance, poor community sanitation has been linked to the transmission of bacteria resistant to virtually all available antibiotics (11-14). Meanwhile, limited healthcare and laboratory infrastructure mean that only about 1.3% of laboratories in 14 African countries can perform routine bacterial culture for AMR testing, which means that resistance often remains undetected and untreated (15, 16). These socio-economic and infrastructural vulnerabilities allow AMR to proliferate in SSA, where WASH conditions are suboptimal (6).

Addressing these challenges requires a One Health perspective that integrates human, animal, and environmental health. Global frameworks such as the Tripartite AMR Workplan and the One Health Joint Plan of Action (2022–2026) emphasize the alignment of antimicrobial stewardship, infection prevention, and WASH interventions across all three sectors. These frameworks offer practical guidance for cross-sector collaboration, acknowledging that AMR arises at the intersection of healthcare, agriculture, and environmental management (17, 18). In the context of WASH, this integration means aligning antimicrobial stewardship and infection prevention and control (IPC) with improvements in water and sanitation systems, wastewater management, and veterinary hygiene practices (7, 13).

From a One Health perspective, WASH deficiencies act as a common conduit linking human, animal, and environmental health. In the human sector, unsafe water and poor sanitation directly increase infection incidence, leading to greater antibiotic use and selective pressure for resistance (18). In the animal sector, lack of clean water for livestock and unhygienic waste disposal facilitates the spread of resistant organisms into food products and local water bodies (17). In the environmental sector, untreated sewage and agricultural runoff enrich soil and aquatic systems with resistant bacteria and antimicrobial residues, creating long-term reservoirs of resistance (19). These domains are interdependent. Resistant bacteria from the environment re-enter food chains, zoonotic pathogens transmit from animals to humans, and human waste contributes back into environmental reservoirs. Such feedback loops demonstrate that WASH gaps are not isolated human health challenges but systemic drivers of cross-sectoral AMR transmission (20).

This narrative review aims to critically examine the role of WASH deficiencies as drivers of AMR in SSA through the lens of the One Health approach. Our scope

is grounded in the recognition that AMR, as a cross-sectoral challenge, cannot be effectively addressed through medical interventions alone. We integrate evidence from human health, veterinary, and environmental domains to illuminate how inadequate WASH infrastructure facilitates the emergence, persistence, and spread of resistant pathogens. In doing so, we align our analysis with the WHO Global Action Plan on AMR and related international frameworks that explicitly identify WASH as a cornerstone of AMR prevention. By synthesizing region-specific data and policy insights, we aim to identify actionable strategies that bridge the gap between AMR control and WASH investment, aligning with the *WHO Global Action Plan on AMR* (21) and the *One Health Joint Plan of Action 2022–2026* (18), offering a pragmatic roadmap for policymakers, researchers, and development partners in SSA.

## Methodology

This study is a narrative review synthesizing recent evidence on the role of water, sanitation, and hygiene (WASH) in antimicrobial resistance (AMR) mitigation within a One Health framework in SSA.

**Search Strategy**

We searched peer-reviewed literature, institutional reports, and policy documents published between January 2015 and January 2025 to ensure contemporary relevance. Electronic databases included PubMed, Google Scholar, and Scopus, supplemented by grey literature from WHO, FAO, Africa CDC, and relevant national ministries.

The primary search terms and Boolean operators were:

- ("antimicrobial resistance" OR "AMR") AND ("water sanitation hygiene" OR "WASH") AND ("sub-Saharan Africa" OR "SSA")
- ("One Health") AND ("antimicrobial resistance" OR "antibiotic resistance") AND ("Africa" OR "low- and middle-income countries")
- ("environmental contamination" OR "wastewater") AND ("antibiotic residues" OR "resistant bacteria")

Reference lists of included articles were also manually screened to identify additional relevant studies. Our search retrieved 612 records. After removing duplicates and applying screening and eligibility criteria, 47 studies were included in the final synthesis (Table 1).

**Inclusion Criteria**

We included sources that met the following criteria:

1. Geographical relevance: Focus on SSA or present disaggregated SSA-specific data.
2. Topical relevance: Address WASH factors, AMR burden, One Health approaches, or cross-sector interventions.
3. Publication type: Peer-reviewed research articles, systematic reviews, narrative reviews, surveillance reports, and technical guidelines.
4. Timeframe: Published between January 2015 and January 2025.
5. Language: Available in English.

Grey literature was considered only if it originated from authoritative institutional sources (e.g., WHO, FAO, Africa CDC, national ministries of health or environment). To ensure reliability, these documents were appraised based on institutional credibility, transparency of data sources, and consistency with peer-reviewed evidence. Reports lacking methodological detail or clear attribution of data were excluded.

**Exclusion Criteria**

Sources were excluded if they:

- Focused exclusively on high-income countries without SSA relevance.
- Addressed AMR or WASH in isolation without discussing potential linkages.
- Were conference abstracts, opinion pieces, or non-substantive commentaries lacking primary or secondary evidence.

**Data Extraction and Synthesis**

For each included source, we extracted:

- Study type (e.g., observational, experimental, review, policy analysis).
- Geographic focus (country/region).
- WASH-related factors (e.g., water quality, sanitation coverage, hygiene practices, wastewater management).
- AMR outcomes (e.g., prevalence of resistant pathogens, antibiotic residue levels, surveillance findings).
- One Health relevance (e.g., cross-sector interventions, zoonotic transmission, environmental reservoirs).

Findings were organized thematically into:

1. Antimicrobial Resistance in SSA

2. WASH Infrastructure and AMR Transmission Pathways
3. One Health Approach
4. Policy and Implementation Challenges
5. Strategies and Recommendations

Given the scope of a narrative review, no formal meta-analysis was conducted. Instead, we synthesized qualitative and quantitative findings to identify cross-cutting themes and knowledge gaps.

**Table 1. Summary of Literature Screening and Selection**

| Stage of Screening | Number of Records | Notes/Reasons for Exclusion |
|---|---|---|
| Records identified through database search | 612 | PubMed, Scopus, Google Scholar |
| Records after duplicates removed | 500 | 112 duplicates removed |
| Records screened (title/abstract) | 500 | - |
| Records excluded | 418 | Not relevant to WASH–AMR link or SSA focus |
| Full-text articles assessed for eligibility | 82 | - |
| Full-text articles excluded | 32 | High-income countries; not WASH–AMR; opinion pieces |
| Studies included in the synthesis | 50 | Peer-reviewed articles, reviews, policy documents, technical reports |

## Antimicrobial Resistance in SSA

AMR poses a severe and escalating public health threat in SSA, where it undermines efforts to control infectious diseases, increases mortality, and strains fragile healthcare systems. The region experiences a disproportionately high burden of AMR, with over 27 deaths per 100,000 population attributable to drug-resistant infections, higher than in any other region globally (2). This burden is compounded by frequent outbreaks of bacterial infections, including typhoid, tuberculosis, and pneumonia, which are often treated empirically due to weak laboratory services and poor access to diagnostics (22).

Key drivers of AMR in SSA include the overuse and misuse of antimicrobials in human medicine, agriculture, and animal husbandry. Antibiotics are frequently sold without prescription, contributing to irrational self-medication and incomplete treatment courses (3). A multi-country survey reported that up to 60% of antibiotic consumption in SSA occurs without any medical supervision (23). In livestock production, antibiotics are often used not only for therapeutic purposes but also for growth promotion, further accelerating resistance transmission between animals and humans through food, water, and soil pathways (14, 24).

Surveillance of AMR remains limited across the continent. A 2023 WHO report found that less than 40% of African countries have national AMR surveillance systems aligned with the Global Antimicrobial Resistance Surveillance System (GLASS), and only a few have fully functioning reference laboratories (25). In many settings, healthcare facilities lack the capacity for bacterial culture, antimicrobial susceptibility testing, and resistance gene identification (5, 7). This contributes to delays in treatment, reliance on broad-spectrum antibiotics, and underreporting of resistance patterns.

Health system limitations further exacerbate the AMR crisis. Inadequate infection prevention and control (IPC) practices, insufficient health worker training, and a lack of essential medicines contribute to high rates of hospital-acquired infections (26). Additionally, limited public awareness and health literacy regarding AMR, especially in rural and underserved communities, hinder appropriate antibiotic use and adherence to treatment regimens (22).

Together, these factors create a feedback loop, poor regulation and weak surveillance fuel inappropriate antibiotic use, which in turn drives resistance, which then leads to more difficult-to-treat infections and increased mortality (23). In SSA, this cycle is particularly

acute due to infrastructural gaps and socio-economic vulnerabilities (7). Addressing AMR in the region, therefore, requires not only antimicrobial stewardship but also broader structural reforms, including improved sanitation, education, and healthcare delivery systems (6).

## WASH Infrastructure and AMR Transmission Pathways

The relationship between WASH and AMR is increasingly recognized as both a driver and a contributor to the AMR crisis. Inadequate WASH systems facilitate the emergence, persistence, and spread of resistant microorganisms in community, clinical, and agricultural settings (6, 27). This is particularly acute in SSA, where significant infrastructural deficits exist. The lack of access to safe water, appropriate sanitation, and basic hygiene practices not only increases the prevalence of infectious diseases but also leads to increased reliance on antimicrobials, often without regulation, thereby escalating resistance rates (25).

To illustrate the interconnected pathways of AMR transmission and potential intervention points, we developed a conceptual model (Figure 1) based on the WHO and One Health Joint Plan of Action frameworks. The model is adapted from the *One Health Joint Plan of Action* and the *WHO Tricycle Protocol* to visualize the flow of AMR between humans, animals, and the environment, and the role of WASH in interrupting these pathways (28).

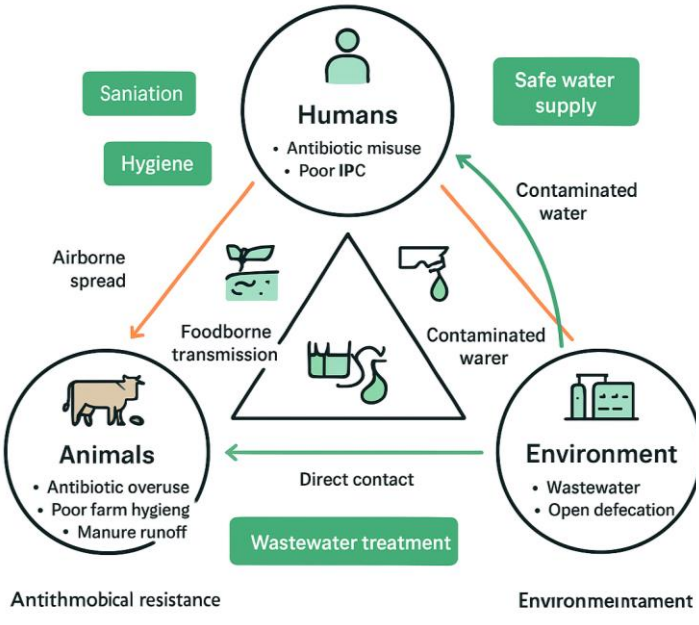


**Figure 1.** *Conceptual model of antimicrobial resistance (AMR) transmission pathways and intervention points under a One Health–WASH framework in SSA (28).*

*WASH deficiencies create reinforcing cycles of antimicrobial resistance. Antibiotic misuse in humans, overuse in animals, and environmental contamination with waste and residues sustain resistant bacteria that move across sectors. Bidirectional feedback loops (arrows) illustrate the cyclical nature of AMR transmission. Interventions such as sanitation, hygiene, safe water supply, and wastewater treatment represent critical leverage points for interrupting these loops.*

One of the primary transmission pathways involves environmental contamination through human and animal waste (12). In SSA, open defecation remains widespread, especially in rural and peri-urban areas (1, 12). According to UNICEF (2021), over 200 million people in the region still practice open defecation (19). This allows fecal matter, potentially containing resistant bacteria or antibiotic residues, to enter surface water sources, groundwater, and agricultural soil.

Recent empirical studies in SSA demonstrate the presence of multidrug-resistant (MDR) and extended-spectrum β-lactamase (ESBL)-producing *Escherichia coli* in both drinking and environmental water sources (29). In Southwest Nigeria, surface water contained ESBL-producing E. coli that harbored blaCTX-M genes and showed resistance to multiple antibiotic classes (30). Similarly, in Uyo, Nigeria, studies of clinical and household tap water detected MDR Enterobacteriaceae, including E. coli, with high rates of ESBL, AmpC, and metallo-β-lactamase co-producers, and frequent blaTEM, blaSHV, and blaCTX-M gene carriage (31). Meta-analyses covering broader regions of Africa reveal that approximately 50.7% of E. coli isolates from water samples are MDR, with substantial resistance to commonly used antibiotics such as ciprofloxacin and ampicillin (32). These findings are consistent with the *WHO Tricycle Project* pilot studies, which have demonstrated that ESBL-producing E. coli is a reliable integrated indicator of AMR across humans, animals, and the environment, and have documented its presence in water sources in Madagascar, Tanzania, and Nigeria (33, 34).

| Study (Country, Year) | Sample Type | MDR/ESBL Prevalence | Key Resistance Genes Detected |
|---|---|---|---|
| Bisi-Johnson et al., Nigeria (2023) | Freshwater surface sources | ESBL-*E. coli* detected (multi-antibiotic resistance) | bla*CTX-M* |
| Akinjogunla et al., Uyo, Nigeria (2023) | Clinical & household tap water | High MDR; ~36.5% ESBL; AmpC & MBL producers also common (~28–62%) | bla*TEM*, bla*SHV*, bla*CTX-M* |
| Meta-analysis (Africa, studies 2000–2021) | Various water sources across SSA | ~50.7% MDR in *E. coli* water isolates | Resistance to ciprofloxacin (13.1%), ampicillin (69.4%), others |

**Table 2.** *Recent studies reporting multidrug-resistant (MDR) and extended-spectrum β-lactamase (ESBL)-producing Escherichia coli in water sources in SSA (32).*

*Note: blaCTX-M, blaTEM, and blaSHV are genes encoding β-lactamase enzymes that confer resistance to β-lactam antibiotics, including penicillins and cephalosporins.*

Healthcare-associated transmission is another critical pathway. Many health facilities in SSA lack basic WASH infrastructure, including clean running water, flushable toilets, soap, and handwashing stations (35). UNICEF (2021) reports that only 51% of healthcare facilities in the region have access to basic water services, and just 23% have basic sanitation (19). This compromises infection prevention and control (IPC) efforts and increases the incidence of healthcare-associated infections (HAIs), which often necessitate antibiotic treatment (26). Furthermore, the overburdened health systems and poor hygiene practices among healthcare workers, due to inadequate facilities, amplify the spread of multidrug-resistant organisms (MDROs) within clinical environments (25). According to WHO/UNICEF JMP (2023), access to basic drinking water, sanitation, and hygiene remains highly variable across SSA (9). Figure 2 visualizes these disparities, highlighting countries where sanitation and hygiene coverage lag far behind water access.

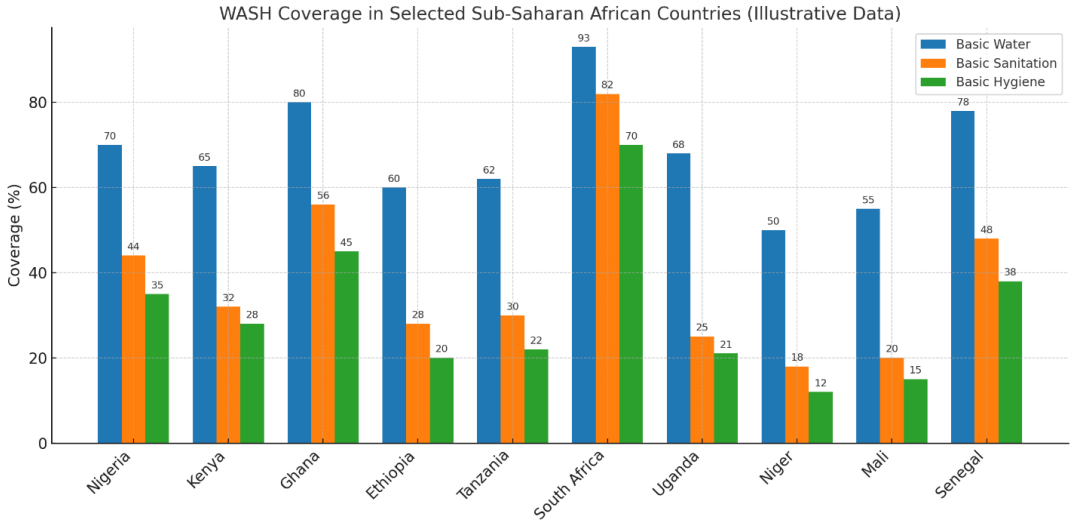


**Figure 2.** *WASH coverage in selected SSAn countries, showing the percentage of the population with access to basic drinking water, basic sanitation, and basic hygiene facilities (illustrative data recreated from WHO/UNICEF JMP 2023) (9).*

Another underappreciated transmission route is related to agricultural practices. Livestock production in SSA frequently relies on antibiotics, not only for treatment but also for growth promotion and prophylaxis (14). However, farm environments often lack

proper sanitation infrastructure. Animal waste, containing unmetabolized antibiotics and resistant bacteria, is commonly used untreated as fertilizer or allowed to contaminate nearby water sources (24, 35). A study by Dickin et al. (2018) emphasized that livestock produce an estimated 80% of global fecal matter, yet are largely excluded from conventional WASH policies (36). This omission creates a major reservoir of resistance that can affect both animals and humans, particularly in farming communities that share water sources and physical spaces with their animals (37).

Foodborne transmission of resistant organisms is also a concern. Poor hygiene in food preparation areas, particularly in informal markets common across the SSA region, allows resistant bacteria to persist and multiply. Contaminated meat, vegetables irrigated with untreated wastewater, and unwashed utensils contribute to the cycle (10, 38). According to Christiana Cudjoe et al. (2022), E. coli resistant to third-generation cephalosporins was isolated from fresh produce and meat in markets in Kenya and Ghana, likely linked to contaminated water used during processing (10). These foodborne pathogens can cause infections that are more difficult and costly to treat, particularly in children and immunocompromised individuals (24).

Additionally, improper disposal of unused or expired antibiotics exacerbates environmental contamination. In many SSA countries, there are no formal systems for pharmaceutical waste disposal. Households often flush leftover antibiotics down the toilet or discard them with regular trash, which eventually enters landfill sites or water systems (12, 39). Pharmaceutical manufacturing waste, particularly in unregulated industrial zones, has also been implicated as a contributor to environmental AMR hotspots (25). This ecological contamination creates opportunities for resistance genes to circulate among environmental bacteria, from where they may be acquired by human or animal pathogens (27, 38).

## One Health Approach

The One Health concept recognizes that human, animal, and environmental health are interconnected. As the WHO notes, One Health "is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems (25). In practice, this means addressing diseases and risk factors across sectors, for example, by improving animal health and habitat alongside human health measures (25). One Health is especially critical for AMR and WASH, because drug-resistant pathogens and antibiotic residues move freely through humans, livestock, food, and the environment (40).

Studies highlight that up to 75% of emerging human infections are zoonotic and that environmental reservoirs (such as contaminated water and soil) amplify AMR spread (11, 41). For instance, WHO emphasizes that resistant organisms "can spread quickly" via animals, food, and water, making AMR control a "multifaceted" problem that requires collaboration across human, animal, and environmental sectors (42). Likewise, a recent review argues that integrated One Health–WASH strategies can improve on-farm biosecurity while also reducing infection pressures on human communities (6, 39).

One Health also implies including WASH in AMR prevention, ensuring safe WASH for both people and livestock. Inadequate sanitation in any domain can drive disease. For example, the WHO points out that antimicrobial residues and resistant microbes are "common and widespread" in wastewater from both human and animal sources, and that "universal access to sanitation, hygiene and safe water" is a priority to reduce infections that would otherwise require treatment (11, 25). In One Health terms, this means targeting contamination at source, improving latrines, water supplies, and waste treatment in both communities and farms, to break cycles of transmission (11, 36, 40). As Dickin et al. (2025) explain, WASH programs typically focus on human feces while overlooking animal waste, yet livestock produce ~80% of the global fecal load (43). A true One Health WASH framework deliberately addresses animal husbandry and environmental sanitation alongside human hygiene (36). One Health approaches to AMR mitigation integrate WASH interventions across human, animal, and environmental sectors (21, 28). Figure 2 illustrates these intervention domains, showing both potential AMR flow and points where WASH measures can disrupt transmission pathways.

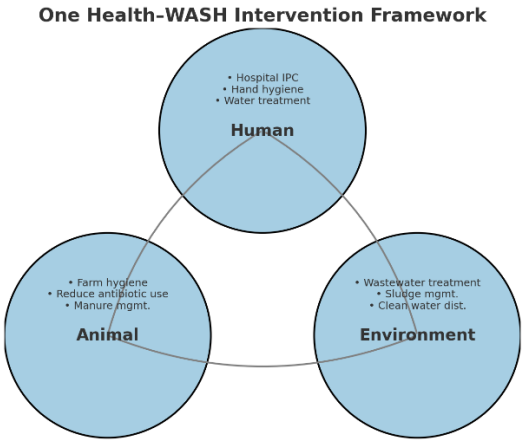


**Figure 3.** *One Health–WASH intervention framework showing key points for antimicrobial resistance mitigation across human, animal, and environmental domains (21, 28). Arrows depict potential AMR flow between sectors and intervention breakpoints.*

In SSA, several African efforts illustrate One Health integration. In Uganda, a recent USAID-supported program explicitly adopted a One Health approach to strengthen the AMR response (4). Working with health, animal, and environmental sectors, it coordinated improvements in infection control (IPC), WASH, and antibiotic stewardship across ministries (4). This intervention trained health workers in facility hygiene, adapted animal-health biosecurity tools, and even brought WASH facility improvement checklists into routine practice in clinics and farms (4). The authors report that best practices in IPC and WASH were shared across at least five partner organizations, and baseline assessments of IPC/WASH were conducted by hundreds of healthcare and animal-health staff (4). In Rwanda, researchers conducted a One Health WASH evaluation of four rural communities, surveying both households and livestock. They found that animals had significantly poorer access to clean water and sanitation than people, and identified one community as having critically low WASH coverage overall (44). They conclude that "multi-sector collaboration among public health, water authorities, and local leaders" is urgently needed so all residents – human and animal – can access safe water (44). Finally, multi-country research networks are forming, for example, a transdisciplinary SEI OneHealth–WASH project that links Burkina Faso, Kenya, and Mozambique to exchange knowledge on reducing zoonoses and AMR through integrated water/sanitation measures (45). Altogether, these initiatives show how One Health thinking, coordinating health, veterinary, agriculture, and WASH sectors, is being translated into practice, even though much more scale-up is needed.

## Policy and Implementation Challenges

Despite the rationale for linking WASH and AMR, policy gaps remain. In many SSA countries, WASH and AMR are managed by separate ministries with weak integration. WHO observes that WASH and wastewater actors are still "under-represented" on AMR multi-stakeholder platforms and in national action plans (20). In practice, sanitation ministries often have their targets (SDG 6) while health ministries drive AMR NAPs, with little overlap (20). Few countries explicitly mention WASH in AMR policy documents, and vice versa. This siloing means opportunities are missed. For instance, a national sanitation strategy may not consider the risk of spreading AMR through open sewage, and an AMR plan may focus on drug regulations without supporting community sanitation (16). In effect, both policy streams may contain gaps that leave environmental reservoirs of resistance unaddressed.

**Multisector coordination and funding** are major obstacles. Coordination bodies and committees often lack authority, clear terms of reference, or financial support (16). A regional survey found that political commitment to AMR in many African countries is low and that governance and regulatory frameworks are weak (16, 20). Only a handful of countries have dedicated budgets for AMR programs, with one report noting just 6 of 31 African countries surveyed had allocated state funding for antimicrobial stewardship, unlike richer nations that typically earmark health budgets for such work (46). This funding gap undermines even well-designed plans (40, 46). Similarly, WASH programs often depend on external aid or local government budgets that are already stretched. Without joint financing mechanisms (e.g., a One Health fund or pooled WASH/health grants), it is difficult to coordinate infrastructure projects and AMR surveillance across sectors (39). Competing priorities – such as malaria control or urban water supply – can draw attention and funds away from integrated AMR-WASH initiatives (20, 46).

At the local level, multiple barriers slow implementation. Infrastructure deficits are severe. Most rural communities still lack reliable piped water or sanitation networks. For instance, only about half of health facilities in Africa have a basic water supply, and under a quarter have proper sanitation (14, 35). Where pipes do exist, intermittent supply, broken taps, or lack of safe drainage can render facilities unhygienic (41). Even

when infrastructure is in place, governance issues can impede use. poor maintenance, corruption, or unclear ownership (who is responsible for repairs) are common (1, 12). Water quality monitoring is often insufficient, so communities may not trust or treat "safe" water. Social and cultural factors also matter. Low awareness of AMR and hygiene means people may continue practices (open defecation, stacking animal pens near homes, or buying antibiotics without a prescription) that undermine health (3, 26, 35). Education campaigns are weak or absent in many areas, especially in remote villages (23). As one review observed, low awareness and training, coupled with economic pressures, drive rampant antimicrobial misuse and poor hygiene practices in African settings (1).

Examples from SSA countries illustrate this uneven progress. Rwanda has been recognized for advancing a strong One Health governance framework, with high-level coordination committees linking human, animal, and environmental health sectors. This has enabled WASH issues (such as safe manure management and water safety plans) to be integrated into its national AMR strategy (47). In Uganda, the National Action Plan on AMR (2018–2023) explicitly included WASH and infection prevention targets in healthcare facilities, yet implementation has faced funding shortages and limited surveillance capacity, slowing its impact (48). In contrast, Nigeria demonstrates persistent challenges, where, although a National Action Plan on AMR exists, enforcement remains weak. Poor inter-ministerial coordination and minimal budgetary allocation have limited integration of WASH into AMR policy, leaving major environmental reservoirs unaddressed (8).

**Opportunities for integration** exist, however. Global initiatives and donor programs are beginning to encourage One Health planning. For example, the WHO/FAO/OIE "technical brief" explicitly urges countries to bring WASH interventions into AMR national plans (49). African governments can leverage these frameworks and partner support to bridge policy divides. Members of the WHO-FAO-WOAH quadripartite already work together on multisectoral collaboration and training in AMR, providing a platform to add WASH expertise. Linking AMR with other national goals also helps, such as incorporating sanitation improvements into pandemic preparedness or UHC strategies, which can attract funding that benefits both AMR and broader health (49). In some settings, AMR and WASH plans can piggyback on successful programs, such as adding antibiotic stewardship components to cholera response teams or using community health workers to teach hygiene and prudent antibiotic use simultaneously (20, 49).

Finally, the rising awareness from the COVID-19 response may catalyze action. The emphasis on handwashing and infection prevention during the pandemic shows that hygiene behavior can change rapidly with political will and resources. If African leaders build on this momentum – explicitly linking clean water and sanitation to antibiotic resistance – they may unlock new investment. Climate resilience funding (for drought-proof water supplies) and antimicrobial-pharmaceutical regulations are other entry points, demanding safe effluent treatment from factories, which benefits both the environment and AMR control (22, 41).

## Strategies and Recommendations

Effective AMR prevention requires **practical WASH improvements** at all levels, ideally designed with community engagement and cross-sector buy-in. Key strategies include:

- **Expand WASH access:** Rapidly increasing safe water supply and sanitation are fundamental. In communities, this means building or rehabilitating wells, boreholes, protected springs, and latrines, with attention to underserved rural and peri-urban areas. In schools, markets, and healthcare facilities, ensuring basic water, soap, and toilets is vital. WHO notes that universal access to sanitation, hygiene, and safe water "is a priority measure to prevent many infections that would otherwise be treated with antimicrobials." (25). Coverage gaps are stark in SSA (for example, only ~51% of health facilities have basic water and 22% basic sanitation, so investment in infrastructure is urgent (50). Donors and governments should align funding (e.g., WASH trusts or SDG 6 investments) to extend piped water, community handpumps, and latrines, and promote household water treatment (4).
- **Promote community-led hygiene.** Empowering local leaders and households to adopt hygienic practices is cost-effective. Community-led total sanitation (CLTS) campaigns, water-user committees, and Village Health Teams can spread handwashing, safe water handling, and waste

disposal messages. Engaging women and schools, especially primary and secondary schools, is particularly impactful. Women often manage family hygiene and water, and school-based programs can model handwashing for children. Evidence shows that basic hand hygiene alone can cut diarrhea by up to 30% (49). Hygiene promotion should be integrated into existing outreach (e.g., immunization drives or HIV/TB programs) and leverage mass media or mHealth reminders. Crucially, these programs should incorporate AMR education, explaining that preventing infection (via clean water, soap, vaccines, etc.) is the first line of defense against antibiotic-resistant disease.

- **WASH in healthcare facilities (HCFs) and farms.** Strengthening infection prevention in HCFs and on farms is a priority. All clinics and hospitals need functioning water points, sanitation blocks, and waste disposal systems. Training all health workers in handwashing and safe injection/cleaning procedures reduces hospital-acquired infections and antibiotic use. Likewise, on farms and in animal markets, basic biosecurity and sanitation (e.g., treated livestock water troughs, manure pits, fenced animal enclosures) are needed. Interventions such as corralling poultry, providing separate animal troughs, or introducing "clean feet" mats for farm entry have been shown to lower zoonotic disease risks (24). By improving farm hygiene (clean water for animals, proper burial/composting of animal waste, and vaccinating livestock), antibiotic use in animals can be reduced, thereby lessening environmental AMR spread.
- **Cross-sector surveillance and coordination.** Effective AMR monitoring in SSA requires surveillance systems that integrate human, animal, and environmental health data. In practice, this means combining hospital-based AMR reporting with environmental and veterinary monitoring to detect emerging threats early. The WHO Global Antimicrobial Resistance and Use Surveillance System (GLASS) provides a global platform for standardizing human health AMR data and is increasingly being adopted in SSA (25). Complementary initiatives such as the WHO Tricycle Project specifically track ESBL-producing E. coli across humans, food, and the environment, making it an ideal model for integrated One Health surveillance (33). In the animal health sector, the FAO Assessment Tool for Laboratories and AMR Surveillance Systems (ATLASS) helps countries evaluate and strengthen veterinary AMR monitoring capacity (15). Linking these platforms, along with periodic testing of water sources, food products, and farm soils for resistant bacteria, would create a more robust and unified early warning system. At the governance level, establishing One Health coordination committees, including representatives from health, agriculture, environment, water, and local communities, can ensure data sharing, harmonized regulations (e.g., on waste discharge), and joint outbreak response training, avoiding siloed interventions and maximizing impact.
- **Fully integrate WASH and IPC into AMR National Action Plans (NAPs) and implementation frameworks.** Countries should fully integrate WASH(WASH) and Infection Prevention and Control (IPC) into their AMR National Action Plans (NAPs) by setting measurable targets for WASH coverage in health facilities and communities, and allocating dedicated budget lines for infrastructure upgrades and hygiene promotion. Ministries responsible for water, sanitation, and the environment must be actively involved in AMR governance platforms to ensure a truly multisectoral response. Aligning agricultural practices with One Health goals, such as through safe manure and wastewater management, will further strengthen efforts to curb AMR at the human-animal-environment interface.

**Table 3. Prioritized Recommendations for Strengthening WASH and AMR Mitigation in SSA**

| Timeframe | Key Recommendation | Responsible Actors | Feasibility & Notes |
|---|---|---|---|
| **Short-term (1–2 years)** | Expand community access to safe water and sanitation through boreholes, wells, latrines, and handpumps | Governments, NGOs, local communities | Feasible with targeted donor/government funding; aligns with SDG 6 |
| | Promote community-led hygiene (CLTS, school programs, women-led initiatives) with AMR education | Local leaders, schools, NGOs, and health ministries | Low-cost, high-impact; evidence shows hand hygiene reduces diarrhea by ~30% |
| | Basic WASH upgrades in healthcare facilities (handwashing points, waste disposal, IPC training) | Health ministries, hospital administrators, NGOs | Highly feasible, requires modest investment |
| **Medium-term (3–5 years)** | Improve farm hygiene and biosecurity (clean animal water troughs, manure pits, fenced enclosures) | Ministries of agriculture, farmers' associations | Feasible with training and subsidies; reduces antibiotic use in livestock |
| | Establish and strengthen One Health surveillance systems (GLASS, Tricycle, ATLASS) | Ministries of health/agriculture/environment, WHO/FAO/WOAH | Moderate feasibility; requires intersectoral coordination and capacity building |
| | Integrate WASH and IPC targets into AMR National Action Plans (NAPs) | National governments, policymakers, and donors | Requires political commitment; improves accountability |
| **Long-term (5+ years)** | Large-scale infrastructure investments in piped water, wastewater treatment, and urban sanitation | National governments, donors, and the private sector | High cost but critical for sustainability |
| | Institutionalize One Health coordination committees across sectors | Governments, development partners, and communities | Sustainable once established; enhances cross-sector policy alignment |
| | Align agricultural waste management with One Health goals (safe manure, wastewater treatment) | Ministries of agriculture, environment, and water | Resource-intensive but essential for systemic AMR prevention |

**Table 3.** *Prioritized recommendations for policymakers to address WASH-related AMR risks in sub-Saharan Africa. Recommendations are grouped into short-, medium-, and long-term actions, with corresponding responsible actors and feasibility considerations.*

## Conclusion

Antimicrobial resistance (AMR) poses an escalating threat to public health, economic stability, and environmental sustainability in SSA. Inadequate WASH infrastructure and practices act as both direct and indirect drivers of this crisis by facilitating the spread of resistant pathogens, increasing the frequency of infections requiring antimicrobial treatment, and enabling the environmental persistence and transmission of resistance genes. Addressing AMR without tackling these foundational WASH deficiencies is not only ineffective but unsustainable.

This review has illustrated the critical intersections between AMR and WASH within a One Health framework, underscoring the need for cross-sector collaboration and integrated action. From community to national levels, practical interventions, such as improving access to clean water and sanitation, promoting hygiene behaviors, and embedding AMR awareness into public health education, can significantly reduce resistance rates and curb unnecessary antibiotic use. These efforts must be woven into broader health systems and aligned with initiatives in food safety, veterinary services, and environmental protection.

Although significant policy gaps and implementation challenges persist, including fragmented governance, inadequate funding, and weak infrastructure, promising models exist. Fully integrating WASH into AMR National Action Plans (NAPs), expanding environmental surveillance, and aligning AMR goals with broader development agendas such as Universal Health Coverage (UHC) and the Sustainable Development Goals (SDGs) can unlock meaningful progress.

In sum, combating antimicrobial resistance in Africa requires more than access to better antibiotics; it demands a transformation of the environments in which people live, work, and seek care. Expanding equitable access to WASH remains one of the most effective and sustainable strategies to disrupt the transmission of resistant infections and safeguard antibiotic efficacy. A One Health–aligned, WASH-centered approach to AMR is not only timely but also essential for long-term regional resilience.

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*Original Article*

# Assessing the Need for Geriatric Care in Uzbekistan Before the Demographic Wave

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**Abstract:**

**Goals.** To assess demographic trends in Uzbekistan (2010–2024) and evaluate the need for geriatric care with a moderate increase in the proportion of persons 65 +, comparing them with health resources.

**Materials and Methods.** Retrospective analysis of official data from the Statistics Agency of the Republic of Uzbekistan (2010-2024): population, share of 65 +, birth rate, mortality, life expectancy, health care resources (beds, doctors, outpatient network). The forecast for 2025 was performed by linear extrapolation (total population: $y = 679.65x + 27.974$, $R^2 = 0.99$; age 65+: $y = 74.05x + 1.140$, $R^2 = 0.98$; 95% CI for 65+ = 2.18–2.28 million). The standard for the need for geriatricians was estimated according to the Russian benchmark of 1 geriatrician/20,000 elderly.

**Results.** The population increased from 28.00 million (2010) to 37.80 million (2024); forecast for 2025 - 38.17 million. The share of 65 + increased from 3.9% (2013) to 5.6% (2024); forecast for 2025 - 5.8% (~ 2.23 million). Able-bodied - 56.2% (2024). In 2023, the provision was 47.4 beds and 28.7 doctors per 10,000 population; outpatient organizations increased to 8011. Circulatory system diseases - 57.6% of deaths (2024). According to the standard, about 112 geriatricians are required with an estimated current availability of 0-100 specialists.

**Conclusions.** Against the background of the low proportion of 65 + and expanding general health resources, the creation of a separate branched geriatric service is not a priority. Rationally - integration of geriatric consultants into large centers (Tashkent, Samarkand, Fergana, etc.) for the management of multimorbidity and geriatric syndromes, while strengthening the prevention of chronic non-communicable diseases in the predominant young population. Monitoring of age-specific mortality/morbidity rates and validated indicators of the functional status of the elderly is needed.

**Keywords:** Population Aging; Geriatric Care; Demographic Transition; Uzbekistan; Chronic Diseases

## Introduction

Population ageing is a global demographic process with significant impact on health systems, social policies and economic structures [1]. In developed countries, such as Japan and Germany, the proportion of people over 65 exceeds 20,0%, which led to the development of specialized geriatric care [2]. In developing regions, including Central Asia, this process is slower, maintaining a predominance of the young population. Uzbekistan shows the following dynamics: the population grew from 28.0 million in 2010 to 36.8 million in 2023 and 37.80 million in 2024, with a forecast of 38.17 million in 2025, while the share of people over 65 increased from 3.9% (1.19 million) in 2013 to 5.6% (2.07 million) in 2024 and 5.8% (2.23 million) in 2025 [3,4]. Despite this, the able-bodied population (16–59 years old) was 56.2% (20.75 million) in 2024, emphasizing the young demographic structure [5].

Uzbekistan's health care system has historically focused on reducing infectious morbidity and improving maternal-child health, which has led to a reduction in infant mortality from 11.0 per 1,000 live births in 2010 to 9.0 in 2024 and an increase in life expectancy from 73.0 to 75.1 years over the same period [6, 7]. However, the increase in the number of the elderly is accompanied by an increase in chronic diseases: in 2024, 57.6% of deaths are caused by the circulatory system diseases of [8]. This raises the question of the need to adapt health care to age-related changes. International experience varies: Japan (28.4% of the elderly) and Russia (15.5%) develop geriatrics, while countries with young demographics, such as India (6.8%), cost common resources (World Bank, 2023) [9].

**The Aim**

Of the study is to analyze demographic trends in Uzbekistan for 2010-2024, assess health care resources and determine the need for geriatric care in a moderate aging setting. The hypothesis assumes that the current infrastructure is sufficient to serve the elderly without creating a specialized service.

## Materials and Methods

To assess demographic trends and the need for geriatric care in Uzbekistan, a retrospective analysis of data for 2010-2024 with a forecast for 2025 was carried out. The main source of information was the official statistical materials of the Statistics Agency of the Republic of Uzbekistan (2025), including data on the population (total, able-bodied, 65 +), fertility, mortality, life expectancy, infant mortality and health resources.

**Data sources**

Data for 2024 were the most recent observed indicators officially published by the Statistics Agency; when 2024 data were unavailable, 2023 values were carried over as baseline estimates. Demographic indicators: total population, number of people over 65 years old, able-bodied population, birth rate, mortality, life expectancy and infant mortality are obtained from the annual reports of the Statistics Agency of the Republic of Uzbekistan (2025).

Health resources: the number of hospital beds, doctors and clinics are extracted from the relevant collections of the Statistics Agency (2025). Forecast 2025: Population and persons 65 + are based on 2010-2024 data and supported by international estimates (United Nations, 2022). All datasets were cross-checked against multiple official statistical releases (2010–2024) to ensure internal consistency. Values were verified with the United Nations and World Bank demographic datasets where applicable.

**Methods of analysis**

The forecast of the population and persons over 65 years old for 2025 is calculated by linear extrapolation. For the total population, the regression equation: $y = 679.65x + 27.974$ ($R^2 = 0.99$), for persons 65 +: $y = 74.05x + 1.140$ ($R^2 = 0.98$), where y is the number (thousand), x are years since 2010. The confidence interval (95% CI: 2.18-2.28 million for 65 +) was determined taking into account the standard deviation of the increase (± 50 thousand).

The need for geriatricians was initially estimated according to the Russian Federation's reference standard (1 geriatrician per 20,000 older adults) [10,11], used here only for orientation in the absence of Uzbekistan-specific norms. However, this ratio may not fully reflect the Uzbek epidemiological context, where primary care and family medicine play dominant roles. An alternative approach could involve integrating geriatric competencies into family doctors' training, developing nurse-led comprehensive geriatric assessment teams, or applying the WHO ICOPE (Integrated Care for Older People) framework rather than establishing a separate specialist network.

The provision of health care resources is calculated as the ratio of the number of hospital beds (174.5

thousand in 2023) and doctors (105.7 thousand in 2023) to the number of elderly in 2024 (2,07 million people). Statistical data processing, including linear extrapolation of the forecast ($R^2$ = 0.98-0.99), was performed in the R software environment (version 4.3.1).

Linear extrapolation was chosen due to the availability of consistent annual national data and the absence of major demographic shocks during 2010–2024. This simple model adequately fits the trend ($R^2 > 0.98$) but does not account for potential nonlinear effects of fertility decline, migration, or policy changes, which may affect long-term projections.

**Ethics and funding**

The study is based on open data, ethical approval was not required. Financing was carried out at the expense of the author's own funds. No conflicts of interest were identified.

## Results

Analysis of demographic and medical data for the period 2010-2024 with a forecast for 2025 revealed key trends in the aging of the population of Uzbekistan, the state of health resources and the structure of morbidity affecting the needs of the elderly. Below are the results based on the official statistics of the Agency of Statistics of the Republic of Uzbekistan (2025).

**Demographics**

The total resident population of Uzbekistan has shown steady growth for 15 years. In 2010, it amounted to 28.00 million, increasing to 30.50 million in 2014, 33.30 million in 2019, 36.80 million in 2023, and 37.80 million in 2024. The forecast for 2025, based on linear extrapolation ($y = 679.65x + 27.974$, $R^2 = 0.99$), estimates the number at 38.17 million. The average annual population growth ranged from 0.37 to 0.75 million people, with a peak in 2020-2023 (about 0.72 million annually), which reflects stable demographic dynamics.

The number of people over 65 has also increased, but remains relatively low compared to the general population. In 2013, the number of people aged 65+ was 1.19 million (3.9%), in 2014 — 1.21 million (3.9%), in 2019 — 1.52 million (4.5%), in 2023 — 1.93 million (5.3%), and in 2024 — 2.07 million (5.6%). The forecast for 2025 was 2.23 million (5.8%) (95% CI: 2.18–2.28 million). The increase in the number of elderly people in 2013-2024 amounted to 0,88 million people (74.2%), or an average of 80.3 thousand annually, which indicates a moderate aging of the population.

The gender structure of the elderly population demonstrates the predominance of women. In 2013, men 65+ accounted for 0.52 million (43.8%), women — 0.67 million (56.2%). By 2024, men increased to 0.92 million (44.3%), women to 1.15 million (55.7%). For 2025, the projection is 0.99 million men (44.4%) and 1.24 million women (55.6%). This ratio reflects the higher life expectancy of women (76.9 years versus 72.5 years for men in 2023) [12, 13].

The able-bodied population amounted to 17.80 million in 2011 (61.2%), 18.81 million in 2014 (61.7%), 19.79 million in 2019 (59.5%), 20.51 million in 2023 (56.9%), and 20.75 million in 2024 (56.2%). The 2025 forecast is 21.04 million (55.1%). The share of able-bodied people decreased from 61.7% in 2014 to 56.2% in 2024 due to an increase in the number of elderly and children, but remains high compared to the global standards of aging societies.

Fertility showed fluctuations: 0.63 million births in 2010 (22.0 per 1,000), 0.72 million in 2014, 0.81 million in 2019, 0.96 million in 2023 (26.4 per 1,000), and 0.93 million in 2024 (24.9 per 1,000). The peak birth rate in 2023 (26.4 per 1000) gave way to a decline in 2024, which may be due to socio-economic factors.

Total mortality increased from 138,4 thousand (4.9 per 1,000) in 2010 to 149,8 (4.9 per 1,000) in 2014, 154,6 (4.6 per 1,000) in 2019, 172,8 (4.8 per 1,000) in 2023, and 174,4 (4.6 per 1,000) in 2024. The jump in mortality in 2020 (175.6 thousand, 5.2 per 1000) is probably associated with the COVID-19 pandemic [14].

Life expectancy at birth increased from 73.0 years in 2010 to 73.4 years in 2014, 75.1 years in 2019 and 75.1 years in 2024, with a temporary decline to 73.4 years in 2020 due to the pandemic. This increase reflects improved population health, although the gap between men and women persists (72.5 and 76.9 years in 2023). Infant mortality declined from 11.0 per 1,000 live births in 2010 to 10.8 in 2014, 9.3 in 2019, 8.5 in 2023 and 9.0 in 2024.

Regional differences are significant: in rural areas, the indicator decreased from 8.8 (2010) to 5.6 (2024), in cities - from 13.2 (2010) to 11.5 (2024), which indicates inequality of access to health services. The higher registered rates in urban settings may partly reflect referral concentration of severe neonatal cases and more complete registration rather than true risk differences. Definitions follow the national statistical methodology, with live births and deaths per 1,000 births.

**Regional population structure**

The urban population grew from 14.43 million (51.5%) in 2010 to 18.77 million (51.0%) in 2024, with a forecast of 19.14 million (51.0%) in 2025 [13]. The rural population increased from 13.58 million (48.5%) in 2010

to 18.03 million (49.0%) in 2024, with a forecast of 18.40 million (49.0%) in 2025. The level of urbanization is stable at 51,0%, which is lower than the average for middle-income countries (about 55,0%) [15].

## Health Reasources

The provision of hospital beds showed wave-like dynamics. In 2010, there were 139.6 thousand beds (47.9 per 10,000 population), in 2014 - 130.9 thousand (42.2 per 10,000), in 2019 - 153.4 thousand (45.2 per 10,000), in 2023 - 174.5 thousand (47.4 per 10,000). For 2024, data for 2023 were adopted as basic (47.4 per 10,000), which is equivalent to 0.0084 beds per elderly person (2.07 million aged 65+) [16]. The number of doctors rose from 72,2 thousand in 2010 to 105,7 in 2023, or 0.00051 doctors per elderly person in 2024. The population per doctor decreased from 378 people in 2014 to 348 in 2023, which remains above the level observed in several upper-middle-income countries (typically 200–300 people per physician, according to international comparative statistics); no official WHO standard exists for this ratio, so this comparison should be interpreted cautiously (World Bank, 2023; OECD, 2023) [17].

The number of outpatient facilities increased from 5,993 in 2010 to 6,054 in 2014, 5,914 in 2019 and 8,011 in 2023, reflecting the expansion of primary care [18]. Therapeutic doctors accounted for 27,9 thousand (37.9%) in 2014, 19,3 (21.1%) in 2019, and 35,0 (33.2%) in 2023, demonstrating an increase in their number, but uneven distribution over the years [19].

**Mortality Structure**

In 2024, out of 174,4 thousand total deaths, 57.6% (100,4) were due to circulatory diseases, 9.4% (16,4) to neoplasms, 5.3% (9,2) to injuries and poisoning, 4.1% (7,1) to digestive diseases, 1.1% (1,9) to infections, and 15.1% (26,3) - other reasons (estimate based on 2023 data). This structure emphasizes the prevalence of chronic diseases characteristic of the elderly, although accurate data by age groups are not available [20].

**Need for geriatric care**

The need for geriatricians for 2025 (2.23 million elderly) amounted to 112 specialists according to the standard of the Russian Federation (1 geriatrician per 20,000 elderly and senile people). The current number of geriatricians in Uzbekistan is estimated in the range of 0-100 based on data from the Ministry of Health of the Republic of Uzbekistan for 2023, which indicates a shortage of 12 to 112 specialists. However, with the proportion of the elderly 5.6% (2.07 million people) in 2024 and sufficient provision of general health resources - 47.4 beds per 10,000 population and 28.7 doctors per 10,000 (according to 2023) - the need to create a specialized geriatric service remains in question (Table 1).

**Table 1. Demographic and healthcare indicators of Uzbekistan, 2010–2025**

| Year | Population (million) | 65+ (million) | % 65+ | Working age (million) | Births (million) | Deaths (thous.) | Beds (per 10,000) | Doctors (per 10,000) |
|---|---|---|---|---|---|---|---|---|
| **2010** | 28,00 | – | – | – | 0,63 | 138.4 | 47.9 | 27.4 |
| **2011** | 29,12 | – | – | 17,80 | 0,62 | 143.3 | 47.3 | 27.7 |
| **2012** | 29,55 | – | – | 18,18 | 0,62 | 146.0 | 46.1 | 27.1 |
| **2013** | 29,99 | 1,19 | 3.9 | 18,51 | 0,67 | 145.7 | 43.9 | 26.8 |
| **2014** | 30,50 | 1,21 | 3.9 | 18,81 | 0,72 | 149.8 | 42.2 | 26.4 |
| **2015** | 31,02 | 1,24 | 4.0 | 19,04 | 0,73 | 152.0 | 41.1 | 26.4 |
| **2016** | 31,57 | 1,31 | 4.1 | 19,25 | 0,72 | 154.8 | 41.1 | 26.2 |
| **2017** | 32,12 | 1,37 | 4.2 | 19,44 | 0,71 | 160.7 | 41.6 | 26.1 |
| **2018** | 32,65 | 1,44 | 4.4 | 19,61 | 0,76 | 154.9 | 46.6 | 27.0 |
| **2019** | 33,30 | 1,52 | 4.5 | 19,79 | 0,81 | 154.6 | 45.2 | 27.1 |
| **2020** | 33,90 | 1,61 | 4.7 | 19,95 | 0,84 | 175.6 | 46.6 | 27.0 |
| **2021** | 34,55 | 1,69 | 4.9 | 20,13 | 0,90 | 174.5 | 46.9 | 27.1 |
| **2022** | 35,27 | 1,80 | 5.1 | 20,29 | 0,93 | 172.1 | 46.3 | 27.9 |
| **2023** | 36,02 | 1,93 | 5.3 | 20,51 | 0,96 | 172.8 | 47.4 | 28.7 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **2024** | 37,80 | 2,07 | 5.6 | 20,75 | 0,93 | 174.4 | 47.4* | 28.7* |
| **2025** | 38,17* | 2,23* | 5.8 | 21,04* | – | – | – | – |

**Estimates. 2023 values used as baseline for 2024.* ***Source:*** *Agency of Statistics of the Republic of Uzbekistan, 2025.*

## Discussion

The study showed a steady increase in the population of Uzbekistan from 2010 to 2024, with a forecast of a further increase in 2025 ($R^2 = 0.99$) [3]. The proportion of the elderly increased from less than 4,0% in 2013 to over 5,0% in 2024, with a slight rise by 2025 ($R^2 = 0.98$), but the able-bodied remain the main group - more than half of the population in 2024-2025 [4]. Life expectancy has increased over 14 years, and the birth rate has slightly decreased by 2024. The country retains a young demographic, differing from Japan and Russia with their high proportion of elderly.

Based on the data obtained, it can be assumed that health care resources are sufficient: the number of beds and doctors increased from 2014 to 2023, providing an acceptable load with the current proportion of the elderly [16,17]. The number of clinics has grown, which has strengthened primary care. Mortality is mainly due to chronic diseases such as circulatory diseases and neoplasms. There are no data on geriatric syndromes, but globally they are not uncommon in the elderly [21]. In Uzbekistan, this does not create a serious burden due to the young structure of the population.

International experience has a diverse structure of geriatric care: in Japan, the most favorable conditions for the elderly and senile, a network of geriatric services is developed. In Russia, the standard of 1 geriatrician per 20,000 elderly is recommended, but implementation is slow due to a shortage of personnel, and India and Vietnam do without the formation of specialized geriatric structures, having fewer resources [10, 11]. Uzbekistan is closer to the latter. There are regional differences in access to services, but they do not change the overall picture.

The need for geriatricians for 2025 is about 112 specialists according to the Russian standard, with the current number of them 0-100. The deficit is small and not critical with a low proportion of elderly and exhaustive resources. Consultants in large centers are enough to fill consultation needs. It is worth noting the limitations of the study - the lack of data on the diseases of the elderly and the possible impact of migration or the economy.

**Policy implications**

Uzbekistan and neighboring Central Asian countries share a youthful demographic profile but are gradually ageing. A phased policy roadmap could include: (1) integrating geriatric principles and screening into family medicine curricula; (2) piloting multidisciplinary ICOPE-style teams in tertiary hospitals; (3) building national registries of multimorbidity and functional decline to prepare for the future demographic wave. Such regional cooperation could enhance preparedness and optimize limited resources.

## Conclusion

The study showed that the population of Uzbekistan is growing, this can be seen in dynamics since 2010, remaining mainly young in 2024-2025. The proportion of the elderly increases annually, but remains low, relative to many developed countries. Health resources, including beds and doctors, are sufficient according to 2023 data to meet the demand of the population. Chronic diseases dominate mortality patterns, but their impact is limited by demographics. The experience of Japan, Russia and India shows that the need to deploy a geriatric service is questionable. It can be recommended to introduce consultants in large centers, such as Tashkent, Samarkand, Fergana and other cities, to solve age problems, while maintaining a focus on youth.

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*Methodological Paper*

# Reporting Practices in Epilepsy Research: An Overview and Tutorial

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**Abstract:**

**Background.** This study examined the reporting practice of subgroup effects of meta-analytic research published in the leading journal of the ILAE.

**Methods.** We selected studies that used ratio measures and employed subgroup analyses. Subgroup differences were calculated as the difference between the log-transformed estimates over the square root of the sum of the squared standard errors. For the calculated test scores, a corresponding two-tailed p-value was calculated using the standard normal cumulative distribution function. The authors also conducted additional analyses accounting for multiple comparisons.

**Results.** The literature search identified 55 publications, of which 14 (25 %) were included. Neither study used a formal test to compare the subgroups. The number of reported subgroup estimates ranged from 2 to 20, and the number of pairwise comparisons ranged from 1 to 53. Overall, there were 187 comparisons, resulting in a median log difference of 0 (IQR 0.12 – 0.17) and a range from -2.92 to 2.32. The median p-value was 0.54 (IQR 0.21-0.85) with 18 (9%) comparisons showing p-values lower than the conventional significance level, whereas 6 and 21 contrasts were $0.05 < p \leq 0.10$ and $0.10 < p \leq 0.20$, respectively. Seven (4%) comparisons resulted in a p-value lower than the corrected significance level when adjusted for multiple comparisons.

**Conclusion.** There was a lack of compliance with the reporting guidelines. The findings from the subgroup analyses were commonly interpreted without employing a formal test. There is need to emphasize the importance of adherence to established reporting standards when presenting the subgroup effects.

**Keywords:** Epilepsy; Meta-Analysis; Subgroup Analysis; Reporting Bias

## Introduction

A meta-analysis provides improved precision and the opportunity to resolve disputes arising from contradicting claims (1, 2). The effect size in a meta-analysis is computed given the variability in a primary study. This inevitably brings a degree of uncertainty, affecting the implications and generalization of the findings. Researchers often seek to conduct a post-hoc analysis to determine the subgroup effect related to the clinical characteristics of a study population.

Subgroup claims can be misleading, especially when certain assumptions are overlooked (1, 3). Existing evidence suggests that the interpretation of findings from subgroup analyses requires particular caution and should not be mentioned in the conclusions (1, 3, 4). The identification of the varying intervention effects requires a comparison of the subgroup estimates. Frequently, inferences are drawn from the absolute differences between subgroups (1, 5), contrasting their significance test results (1, 3-6), visual inspection of confidence intervals overlap, or other contrasts that lack control over multiple comparisons (1, 6, 7). These approaches, however, barely reveal group-wise differences in effects or lack thereof.

There are general principles that should be considered when analyzing and interpreting subgroup effects (3, 8). However, the quality of reporting of statistical findings remains poor (4). Previous works provided detailed discussions of issues arising from subgroup analyses referring to clinical trials (3-6). However, it has rarely been the subject of interest in the context of meta-analysis. We conducted this study, to explore the current reporting practice in meta analytic research and discuss potential issues when interpreting the subgroup effects.

## Materials and Methods

**Search strategy and study selection.**

To identify meta-analyses, we manually searched the database of Epilepsia, the leading journal of the International League Against Epilepsy (ILAE) (9). The literature suggests that the number of published meta-analyses has notably increased over the last decade (10), with ratio measures being the most employed measures of association (11). Therefore, the authors screened only publications from January 2015 to August 2025 and selected only studies that employed ratio measures such as Odds Ratio (OR), Risk Ratio (RR), or Incidence Rate Ratio (IRR). Studies that did not report subgroup analyses or ratio measurements were excluded.

**Data extraction.**

A standardized data extraction form was developed using Microsoft Office. For the publications included, appropriate research details, such as the year of publication, measure of effect, effect size, and confidence intervals, were extracted. This was a brief literature review and was not preregistered. The extracted data and analytic code are available within the publication.

**Statistical analysis.**

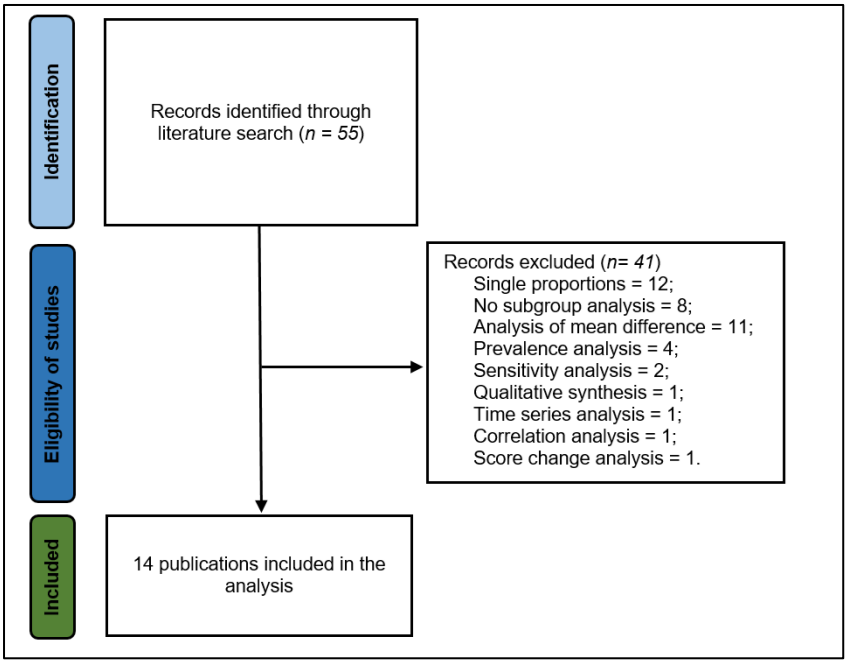
Unlike previous PRISMA statements (12), the latest PRISMA guidelines (13) provide an extended checklist with a clear requirement to report on how subgroup effects were analyzed, as well as the corresponding p-values and 95% CI for an estimate. We used log-transformed estimates of effect sizes. When confidence intervals were not reported directly, they were calculated using the conventional approach (14). The Standard Errors (SE) were approximated by dividing the width of the confidence interval by 3.92, and the difference between the subgroups was calculated as follows: (β1 - β2) / [sqrt(SE1)2 + (SE2)2] (15, 16). We then calculated a corresponding two-tailed *p*-value as $p = 2\Phi(-|z|)$, where $\Phi$ is the standard normal cumulative distribution function. We also performed additional analysis to account for the familywise error rate by employing a Bonferroni correction as $\alpha$/n, where $\alpha$ and n are significance level and the number of comparisons conducted within a specific meta-analysis, respectively. Data were reported as percentages for categorical variables and as median and interquartile range (IQR) for continuous values. The corresponding code used for data analysis is available in the appendix (Supporting Information, Analysis R code).

## Results

Overall, the literature search identified 55 publications, 41 of which did not meet the inclusion criteria. The excluded articles represented an analysis of single proportions (n=12, 22%), did not report subgroup analysis (n=8, 15%), and calculated standardized mean difference (n=6, 11%), mean difference (n=5, 9%), prevalence analysis (n=4, 7%), sensitivity analysis (n=2, 4%), qualitative synthesis (n=1, 2%), time series analysis (n=1, 2%), correlation analysis (n=1, 2%), and analysis of change in a score (n=1, 2%). Consequently, our final

analysis included 14 (25%) studies (17-30) (Figure 1, Supplemental Table 1).

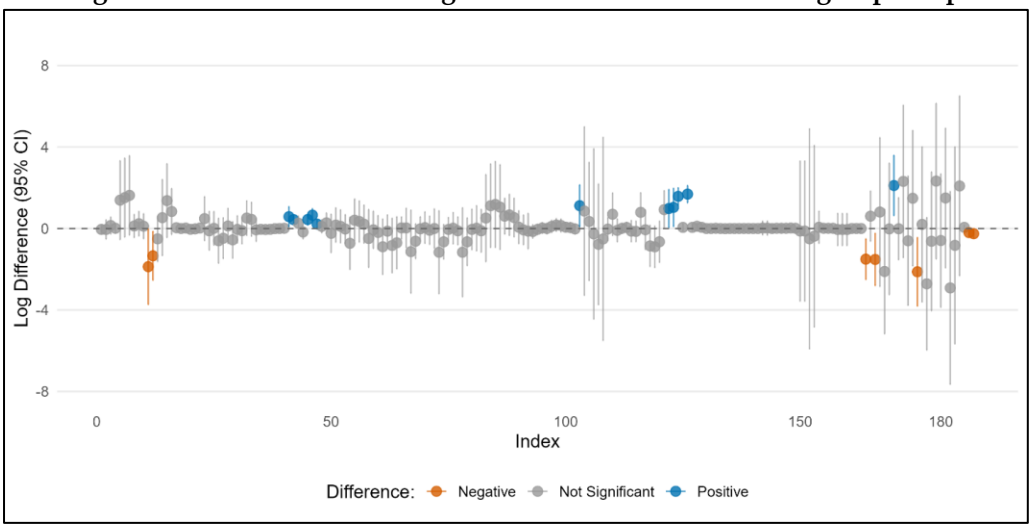
**Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.**


Identification
Records identified through literature search (n = 55)
Eligibility of studies
Records excluded (n= 41)
Single proportions = 12;
No subgroup analysis = 8;
Analysis of mean difference = 11;
Prevalence analysis = 4;
Sensitivity analysis = 2;
Qualitative synthesis = 1;
Time series analysis = 1;
Correlation analysis = 1;
Score change analysis = 1.
Included
14 publications included in the analysis

The included studies mostly used RR (n=7, 50%), followed by OR (n=6, 43%), and IRR (n=1, 7%) as measures of effect. Ten studies (71%) (17, 19-21, 23, 25-27, 29, 30) mentioned a planned subgroup analysis in the Methods section, and two (14%) (17, 29) incorporated individual participant data (IPD). However, neither study used a formal test to compare the subgroup effects. Seven (50%) studies (19, 21, 22, 24, 27, 29, 30) used subgroup analysis to explore heterogeneity, and eight (57%) studies (17, 20-22, 25, 26, 28, 30) mentioned subgroup findings in the conclusions.

The number of reported subgroup estimates ranged from 2 to 20, whereas the number of corresponding pairwise comparisons ranged from 1 to 53 (Supplemental Table 1). There were 187 unique subgroup comparisons that resulted in a median log-difference of 0 (IQR 0.12 – 0.17), ranging between -2.92 and 2.32 (Figure 2).

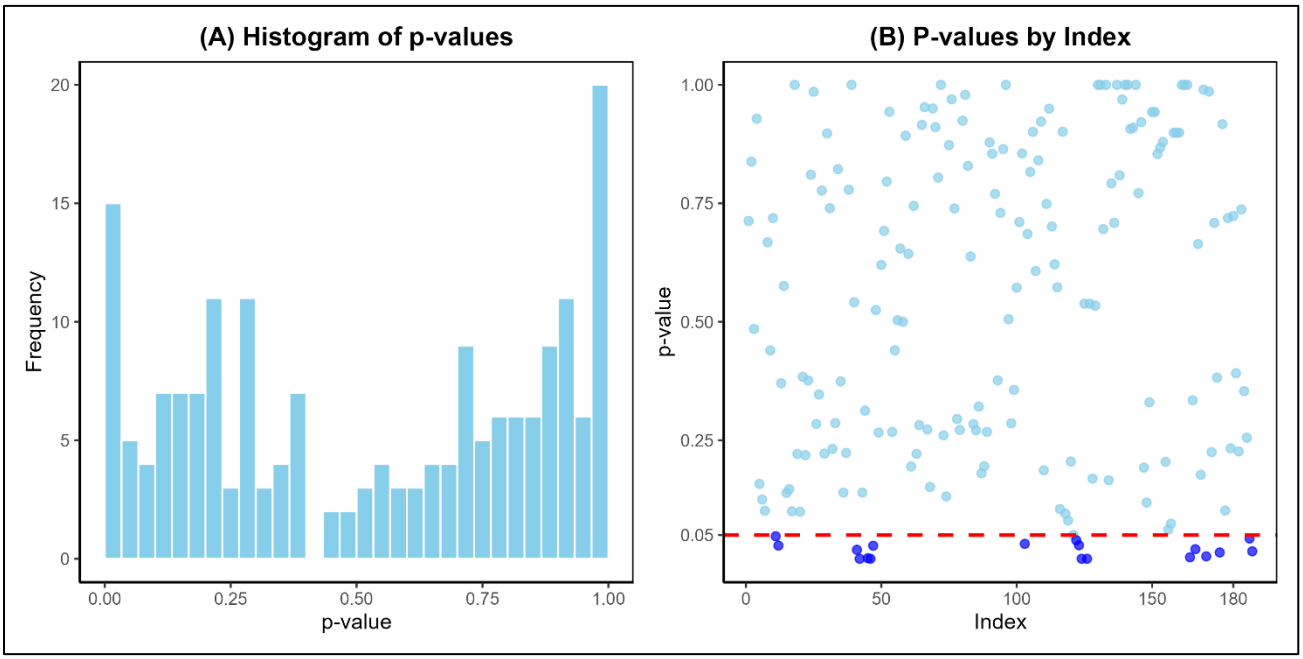
**Figure 2. Distribution of the log-scale difference between subgroup comparisons.**




*CAPTION: Index stands for the unique comparison; log-difference was calculated as (β1 - β2); 95% CI was calculated as log-difference ± 1.96 SE; SE was the square root of [(SE1)2 + (SE2)2].*

The corresponding median p-value was 0.54 (IQR 0.21-0.85) (Figure 3A). Of the 187 comparisons, 18 (9%) revealed a p-value lower than the conventional level of significance, whereas 6 (3%) and 21 (11%) contrasts were $0.05 < p \leq 0.10$ and $0.10 < p \leq 0.20$, respectively (Figure 3B). Furthermore, when adjusting for multiple comparisons within a study, only seven (4%) comparisons resulted in a p-value lower than the corrected significance level.

**Figure 3. Distribution of p-values comparing log-scale subgroup differences.**




*CAPTION: Index stands for the unique comparison; (A) Histogram of p-values for log-transformed differences between subgroups; (B) Scatter plot of individual p-values by index, with a horizontal line at the conventional significance threshold (0.05); The p-values for each index were calculated using the test score and standard normal distribution.*

## Discussion

This study identified several issues in the current reporting practices in meta-analytic research. Our main findings are following:

- A quarter of all meta-analyses did not use interaction tests when comparing subgroups;
- A post-hoc comparisons showed statistical evidence in 9% of cases;
- Tests corrected for multiple comparisons showed that 4% of the contrasts had statistical evidence of differences;

The interpretation of subgroup effects was mostly ignorant of the appropriate statistical tests. Most subgroup differences did not reveal statistical evidence. There is also a lack of corresponding statements in the Methods section and inappropriate mentions in the Conclusions section regarding subgroup effects.

Running numerous subgroup analyses to explore heterogeneity remains questionable (1, 31). Seven (50%) studies used subgroup analysis to explore the causes of heterogeneity (19, 21, 22, 24, 27, 29, 30). On the one hand, the existing PRISMA statement (13) needs the specification of methods to analyze heterogeneity, implying a subgroup analysis or meta-regression. However, the literature suggests that reliable inferences can only be drawn from pre-specified analyses (1). Furthermore, explorations of heterogeneity upon the heterogeneity is observed (which was mostly the case) can only enable the generation of hypotheses rather than making any conclusive claims (1). This also calls into question the evaluation of heterogeneity when the number of primary studies is limited (1, 32). These controversies might affect reporting practices and highlight the importance of clarifying when stratification analyses are appropriate and when they are not.

There is a suspicion that researchers may selectively report subgroup analyses, making it difficult to understand how many "less interesting" findings were left out (4, 6, 31). Hence, when conducting a test with a 95% confidence level, the one remains with a 5% chance of a Type I error. For instance, one study (17) had 30 comparisons. Conducting such a number of tests at the

conventional significance level suggests a 79% probability of at least one contrast falsely rejecting the null. Thus, under the assumption of a 5% Type I error rate, we would anticipate 1.5 ≈ 2 falsely observed "statistically significant" differences. Indeed, the crude comparison revealed two indices with statistical evidence of difference, which is exactly the same as we would expect by random chance. However, when applying the Bonferroni correction for this study (0.05/30), no contrasts were lower than the adjusted significance level. This underscores the importance of transparent reporting of the number of comparisons made, as well as correcting for multiple comparisons to avoid inflation of Type I error.

Most subgroup analyses from systematic reviews are limited by between-study comparisons (3, 8). However, this is an exclusion for the meta-analysis of IPD. Two studies incorporated IPD (17, 29). However, the authors did not formally test the differences between the meta-analysis of aggregated data and the meta-analysis of IPD, which may limit the implications of the findings.

This study represents a brief overview of a current reporting practice, providing a tutorial for comparing subgroup effects. However, our literature search was restricted to a single journal. Therefore, our findings may only be applicable to publications in the field of epilepsy research. Our results are solely based on available reports; some studies may not have fully disclosed data on the outcomes of subgroup analyses. We also focused only on studies that used ratio measures, which represented 25% of all meta-analyses. It would be interesting to obtain data on other measures of association and determine how they would affect our findings and suggestions. Finally, we observed a handful of comparisons that provided statistical evidence of differences. However, a large effect with a large p-value may have more practical importance than a small effect with a small p-value (33). For instance, our (exponentiated) differences ranged from 0 to 10, indicating the possibility of meaningful effects, albeit not being "statistically significant." Furthermore, included studies differed in research areas. Therefore, our findings are by no means to be interpreted as lacking in practical relevance; rather, we aimed to draw attention to the importance of formal statistical tests when inferring from subgroups.

## Conclusion

We searched the content of leading ILAE journal over the past decade. We found that all the findings from the subgroup analyses were interpreted separately without employing appropriate statistical tests. The vast majority of our subgroup comparisons resulted in weak evidence against the null hypothesis of no difference. Medical journals may require both researchers and reviewers to be aware of the importance of adhering to reporting principles to improve the implications of their findings.

## Supplementary Materials

Supplementary Materials include:

- R code used for data analysis
- Supplemental Table 1. Characteristics of included studies.

Supplementary file available via: https://www.journalehdi.com/suppfile/730/Supplemental-materials.docx

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